VI. *On some recent Improvements made in the Mountings of the Telescopes at Birr Castle.*

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[PLATES 11-13.]

FOR some time in carrying on the work of the Observatory at Birr Castle the mountings of the instruments had been found yearly more and more deficient in the requirements of modern astronomy. The six-foot reflector still remained unequalled in aperture, and even the three-foot was in two or three cases only surpassed or even approached in size, but the mechanical appliances for working them were by no means equal in convenience to those fitted to most modern instruments, so that much time was unprofitably spent, and in some departments of the science we found it impossible to make progress. It was therefore decided, in the first place, to apply a clock-movement to the six-foot, the motion of which in Right Ascension had up to that time been given by the hand of an attendant.

The mounting of the six-foot reflector had proved perfectly successful as to steadiness and ease of working, and with the means available for its execution at the time, perhaps, it was the only one which could have been well carried out, but in its limited range of motion we latterly found a considerable inconvenience, which increased as the re-observation of HERSCHEL'S catalogue proceeded, and when the spectroscope came to be applied to astronomical investigation the drawbacks to it were found still greater.

Six-foot reflector.

In the year 1869 the clock-movement was applied to the six-foot instrument. This was a matter of some difficulty, as the resistance to be overcome was not only on an average greater, but also, owing to the counterpoising being approximate only, more variable* in amount than in any other example; still the clock has been so far successful as to have been of immense advantage in working with the filar micrometer.†

* In some positions of the telescope the unbalanced pressure with or against the motion in Right Ascension reaches the large amount of 400 lbs., while the weight to be moved—tube, speculum, &c.—probably exceeds 10 tons.

† The suspending chain admits of a very considerable departure of the telescope from a given declination, considerably more than the length of the slit of a spectroscope, owing to the variable amount of "sag" of the chain, so it was useless to seek for so accurate a motion in Right Ascension as would keep a star's image within the breadth of the slit.

The clock has a train of five arbors, the first, carrying the barrel, being worked by a weight of about 30 cwt. (acting through a single pulley) descending half a foot per minute. The fifth carries a ball-governor like that usually adopted but with a higher velocity, and springs are employed to assist gravity in acting in antagonism to centrifugal force. A pulley (A) fixed upon the third axle transmits the motion through the medium of an endless rope of galvanised wire to a pulley (D) (Plate 11, figs. 1, 2, and 3), fixed at the eastern end of a wrought-iron pipe (G H). A weighted lever with a pulley (C) at its extremity serves to keep the wire-rope at the requisite degree of tension. The pipe (G H) is supported near its centre of gravity from a beam (E E) by a standard (K) with a set of rollers in a live ring, and is prevented from moving endwise towards G by an annular bearing, and towards H by a centre bearing. The beam at its eastern end rests, through the intervention of a strong piece of T-iron, provided with rollers, against a circle of about 40 feet radius (which remains fixed to the eastern wall as heretofore). The beam runs through a socket provided with rollers (R R). The socket is attached to the tube (a portion of which, O O, P P, is shown) by a pin (M), and follows the angular motion of the beam as the tube of the telescope moves westwards. The pipe is fitted with a nut at G, into which a square-threaded screw (I G) of four threads to one inch works. The telescope can be advanced or drawn back in Right Ascension by the observer by turning the screw by means of the pulley I.* A clamping screw in the socket (J), through which the end of the screw passes, prevents the screw from turning round with the nut when the clock is going. The socket J is bolted to the socket R M, L R, and so connected with the telescope. The beam (E F) is faced with strong hoop iron. The greater part of the pressure of the beam, pipe, and screw in a direction tangential to the circle of motion in polar distance is carried by a lever and counterpoise attached at N, but not represented. The east end of the screw is turned down for a length of two or three inches, and is provided with a washer with rounded edge which keeps that end of the screw from lying upon the inside of the tube. Plate 11, fig. 1, shows the general arrangement of the screw in elevation, looking northwards, with the telescope directed to the zenith; fig. 2 is a cross section of the beam, &c., at G L; fig. 3 is a general view of the whole on a smaller scale, looking westwards.

It will be observed that the rate of the clock must be made to vary in proportion to the cosine of declination. No automatic contrivance has been applied for effecting this; but, as for obvious reasons we as far as possible restrict our observations on each night within a limited range of declination, the alteration of the rate by hand has not been found to cause serious inconvenience.

* This motion is rarely used, as the eye-piece has a motion of 15′ or 20′ range in an east and west direction, by means of which an object can be followed. The small speculum also having a clear aperture of nine inches, little or nothing of the pencil of rays is cut off within this range.

The three-foot reflector.

The three-foot reflector had up to the year 1874 been carried by an Altazimuth mounting constructed principally of wood, which, though possessing this advantage over that of the six-foot—that the instrument could be directed to any part of the visible heavens—was from its nature less convenient for general work, and did not possess the steadiness of that of the six-foot, or of a mounting composed wholly of metal and masonry. The woodwork was in need of extensive repair, and it was decided to remount the instrument as an equatorial of such strength and solidity as to be as far as possible free from vibration even when exposed to a moderate force of breeze.

The mounting now most in favour both for reflectors and refractors, which has been recently much improved in details by Mr. GRUBB and others, and modified by the late Mr. GRUBB in the case of the great Melbourne telescope by placing the upper bearing of the polar axis above instead of below its intersection with the declination axis, with the object of securing greater steadiness and ease of motion in so large a reflector, is that known as FRAUNHOFER'S.

In it the tube of the telescope is situated at one extremity of the declination axis, and it is counterpoised round the polar axis by a weight at the other extremity of the declination axis. In following an object with a telescope mounted on this plan from near the eastern towards the western horizon it is, in general, necessary that the tube shall be "reversed" from one side to the other of the polar axis at or near to the meridian (usually the best position for observation). This is certainly a cause of considerable inconvenience in some classes of work.

In the mounting about to be described "reversal" is also necessary, but only at the less advantageous positions for observation, the east and west points. The tube is balanced round the polar axis, and the only part which requires a counterpoise is the fork which carries the tube.

The mounting adopted by Mr. LASSELL for his two-foot and four-foot reflectors furnished the original idea, but with the kind assistance of Mr. BINDON B. STONEY, C.E., from whom many valuable suggestions were received, as also through the careful attention given to the designing of the details of the various parts by Mr. W. G. STRYPE, C.E., who was the first to suggest the form of fork ultimately adopted, and superintended the execution of the whole, it is hoped that the mounting may be found well adapted for the work required.*

In Mr. LASSELL'S mounting the polar axis consists of a cone of boiler-plate, the apex of which is directed towards the south pole and rests in a step or bearing. The upper end is covered in with a plate, upon which are erected two standards which support the two extremities of the declination axis. The base of the cone turns upon antifriction rollers.

* Mr. WILLIAM SPENCE, of Cork Street, Dublin, was contractor for the work, masonry only excepted.

In modifying this mounting we endeavoured to make the polar axis as much a continuous girder as the conditions to be fulfilled admitted of. The upper bearing was placed externally to the structure and was reduced to a small diameter. Unlimited freedom of motion round the polar axis was thus sacrificed; but it is believed that a more rigid and steady mounting has been obtained which, without the introduction of antifriction rollers, turns with at least equal ease in Right Ascension. The mounting (Plates 11, 12, and 13) is carried by a massive pier of stone laid in cement-mortar, on the southern inclined face of which rests a bed plate (A A, B B) of cast-iron, ribbed on its under side, imbedded in cement and fixed firmly down by six bolts, four of them near the lower and two near the upper edge of the plate, and all extending deep into the masonry. Upon this rests, with power of adjustment in both planes, the pedestal casting (C), which is bored to receive the polar axis, a wrought-iron bar with slightly conical bearing surfaces near its ends fitted into it. A cotter and wedge received by a slot through its centre press it down firmly home, and the same when reversed in position can be used to start it up from its place if at any time required. The pedestal casting is provided with a lip which catches the top edge of the bed-plate, keeps the former from sliding down, and takes off all side pressure from the adjusting screw, D. The centre of gravity of the whole overhangs the upper edge of the base-plate a little.

The fork is tubular and made of boiler-plate $\frac{1}{4}$-inch thick, firmly rivetted to angle iron, of $2\frac{1}{4} \times 2\frac{1}{4} \times \frac{5}{16}$-inch scantling, along each angle in the usual manner. The web of the lower part is carried up and connected to the base of the fork at F F to give greater rigidity. The fork, as will be seen from Plate 11, fig. 4, turns on conical bearings of small diameter. The bearings are of hard brass. Their external surfaces are cylindrical, and they are fitted into castings rivetted to the plating of the fork. The bearings can be turned round,* and thus, the common axis of the conical cavities being inclined at an angle of about 13′ from that of their external surfaces (the cavity in the lower one being eccentric by $\frac{5}{16}$ of an inch), an adjustment for perpendicularity of the declination to the polar axis can be made, and no provision for adjustment of the bearings of the declination axis is needed. The counterpoise of the fork is marked W in the drawings.

The tube turns on cylindrical trunnions which have conical ends fitted into castings rivetted to the sides of the tube. They are retained securely in their places by feathers, nuts, and lock-nuts. The pressure of the tube parallel to the declination axis is communicated through the shoulder of the lowermost trunnion to the corresponding branch of the fork, and also equally to the other branch through the washer,

* Both bearings are provided with graduations, so that they may be turned round by an exactly equal amount, and that thus the axis of each may continue parallel to the axis of the bar, the whole describing a conical surface round the common axis of the external surfaces of the bearings. The component of the motion in the plane of the declination axis is that which effects the adjustment, that perpendicular to that axis having no effect beyond a slight disturbance of equilibrium round the polar axis.

nut, and lock-nut on the uppermost trunnion. It will be observed that the sides of the tube are expanded to 50 inches at the trunnions to give greater steadiness. The diameter of the speculum is about 36 inches, but the mouth of the tube has a clear aperture of $39\frac{1}{2}$ inches, so that no light may be cut off within a field of 40′ diameter. It will be observed that, unlike Mr. LASSELL's and that of the great Melbourne telescope, the tube is square. It also differs from Mr. LASSELL's in this—that the brass ring (G, Plates 12 and 13) at its upper end is the only part which can be turned round the axis of collimation, but this motion meets all requirements of convenience in observing. The ring is retained in a nearly central position by three blocks of brass, provided with shoulders, against which its inner edge rests. The outer edge of the ring is chamfered off, and each block is provided with a screw (S) and a piece of brass, by simply tightening or slackening any one of which the ring is made free to move or firmly clamped.

The tube is made of angle iron, the longitudinal bars $1\frac{1}{2}\times1\frac{1}{2}\times\frac{1}{4}$-inch scantling, and the lattice bars $1\frac{1}{8}\times1\frac{1}{8}\times\frac{3}{16}$-inch above the trunnions and $1\frac{1}{2}\times1\frac{1}{2}\times\frac{1}{4}$-inch below them. The upper end of the tube for a length of 12 inches is made of plating of about $\frac{1}{10}$-inch thick, and cylindrical in order that the corners may not interfere with the apparatus attached to the eyepiece. The supports at the back of the speculum continue the same as they have been since it was first mounted, and it has on that account been considered unnecessary to complicate the drawings by representing them.* The pressure on its edge in every position is now borne by a ring of angle iron, suspended from the speculum box by eight rods, linked to it as shown in dotted lines ($l\,m$, $l\,m$) in Plate 11, fig. 4, those which happen to be uppermost taking the weight of the speculum, and the ring is free to move parallel to the axis of the tube as much as may be rendered necessary by the elasticity of the back supports. The eight rods pass freely through holes in the framing of the tube and are screwed and fitted with nuts to tighten them, so that the position of the speculum may change as little as possible on passing from one side to the other of the zenith.† The speculum box is of cast-iron, and it has a second bottom of wood, for the purpose of enclosing an air-space to be heated by a very small lamp, so that a small amount of heat may penetrate through the first or cast-iron bottom to the speculum and thereby diminish the chance of deposit of dew upon its surface. The space between the upper edge of the box and the edge of the speculum is closed in with wood and canvas.

The coarse motions both in Right Ascension and in declination are effected by means of worm-wheels of a pitch of two threads to one inch, bolted respectively to the lower end of the fork and to the extremity of one of its branches. The worm geering into the latter is fixed on to an arm turning on the trunnion and held in position by a screw of eight threads to one inch pitch, which gives the fine movement in declination

* Their principle has been fully described in the Phil. Trans. for 1861, Part 3.

† A collimator has been fitted to the interior of the tube to enable the position of the speculum to be corrected.

in the usual manner, and is brought within reach of the observer by means of a wire rope passing over pulleys. Each worm is cut across at the centre of its length and one portion is free to slide lengthwise, so that any shake can be removed by tightening the nut and lock-nut at the outer side of one of the bearings.*

Gallery.

The construction of a gallery to enable the observer conveniently to reach the eye-piece has been considered as one of the greatest difficulties to be overcome by the designer of an equatorial mounting for a Newtonian, and it seems to have led to the Cassegrain form being preferred for the great Melbourne reflector. However, I was deterred from adopting the latter construction by what appeared to me the greater difficulties and inconveniences inseparable from it, as also by the risk of fracture of the speculum in boring out its centre. The following form of gallery was adopted as being apparently liable to the least objections.

A circular wall of brick and cement, whose centre nearly coincides with the centre of motion of the mounting, carries a wrought-iron rail (L). On this a wooden, iron-bound framework (O P, Q N) provided with wheels at M, N, O, runs and carries an arm (T U) provided with worm-wheel horizontal and altitude motions. From the extremity of this arm is suspended the platform on which the observer stands. It will then appear that the gallery has three motions, one in altitude and two in azimuth, and one only of them, that of the frame upon the railway, has not been brought under the easy control of the observer. By means of them and the power of turning the ring at the mouth of the tube, the observer can reach the eye-piece in comfort in every position of the telescope, except at low altitudes, where a light independent ladder is used. The arm which carries the platform is constructed of four deal rods sprung out, connected by pairs at their upper ends, and firmly held together at each cross strut by hoop iron. A cast-iron counterpoise (W″), weighing about 1650 lbs., is fastened immovable on the prolongation backwards of the arm, which it balances when 400 lbs. weight is placed upon the platform. In observing, equilibrium is restored by keeping between the bottom (which is of sheet copper) of the gallery and the floor just so many lead weights as will, with the weight of the observer or observers, just make up the 400 lbs. Two counterpoises (W′, W′) serve to bring the centre of gravity of the gallery within the wheel-base, as otherwise the wheels at N and O would not rest on the rail.

* Since the erection of the instrument it has been found impossible so to adjust the nuts and lock-nuts that the worms shall be quite free from shake and yet turn with sufficient freedom, but one-sixth of a turn of a helical clump, since fitted to each and working between the end of the worm and its bearing, and under the control of the observer, meets the difficulty.

Clock-movement.

The clock-movement is of the ordinary construction with centrifugal ball-governor, bringing into play as a checking force the friction between leather studs, connected with the balls and a fixed brass ring. Usually the governor has been so adjusted as to give unaided slightly too high a velocity, and its controlling force has been supplemented by one brought into play by a bevel-wheel running between one moving with the train and one connected with a scape-wheel and seconds pendulum. Any excess or defect of velocity of the train produces a motion of the intermediate wheel, accompanied by an elevation or depression of a lever in connexion with it, thus bringing it into contact with, or withdrawing it from, a rapidly revolving disc worked by the train. The arrangement is not novel.*

The method by which the motion of the clock is communicated to the telescope is peculiar. On the lower end of the fork is fitted a sector of six feet radius. It has an arc of nearly 40°, giving a run of over two hours. Its face is smooth. The motion of the clock is imparted to a square-threaded screw (V X), and to the nut working on it are attached two straps of sheet brass, which wrap round the face of the sector and are fastened to it at its eastern end. A third brass strap fastened to the western end of the sector and wrapping round it between the other two keeps them in a proper state of tension, and a bow (*j k*) connected with the nut by a universal joint at *p* and at *q* fastened to the strap gives the tension to the straps, so that the sector and nut are practically rigidly connected with one another. A coupling at V connects the screw with a handle for winding back, and a pulley, round which passes an endless rope up to the gallery, and a pinion geering into the spur-wheel enables the observer to move the telescope forward or backward in Right Ascension by turning the nut.

The mounting has now been completed about three years; but as our attention has been up to this specially directed to the clearing up of doubtful points in former observations of the Nebulæ which came to light on preparing them for publication, that the work of the six-foot since its erection might be brought out in as complete a form as possible, comparatively little work has been engaged in as yet with the three-foot; however, it has been fairly tested as regards its steadiness, and no tremor through the action of the wind was noticed. The fine motions both in Right Ascension and Declination, the two motions of the arm of the gallery, and the clamps are within easy reach of the observer when in the gallery. It is intended to add an arrangement for reading the Declination circle from the gallery, and it is hoped that some sufficiently simple means to enable him to read the Right Ascension circle may be devised, and if these additions can be satisfactorily carried out they will, of course, be of immense service to the observer, as now time is lost in descending for the purpose of making the set.

* The late Mr. Cooke, of York, and Mr. Howard Grubb, of Dublin, have employed similar devices for the control of equatorial clock-movements.

The Right Ascension circle is represented at Y, and the declination circle is fixed on to the axis at Z.

Plate 11, fig. 4, represents the mounting as seen in a direction parallel to the plane of the equator in the meridian and in a direction at right angles to it, the Declination axis lying east and west, and the tube directed towards the pole.

Plate 12, fig. 5, shows the mounting as seen from the west, the tube being directed towards a point in the meridian a little north of the zenith. The gallery is shown placed in position for observing.* The wall which supports the rail (L), and which has two openings, one on the south side to afford a space for the fork to move in, and the other at the north side for the admission of the speculum after repolishing, and to afford access in working the telescope, has now been omitted from the drawing to avoid complexity.

Plate 13, fig. 6, represents the mounting in plan, the telescope being directed to the zenith and the gallery lowered to the ground.

* There is a slight inaccuracy in the position of the speculum arm in fig. 5. It is screwed on to the ring at a point at right angles to that occupied by the eyepiece as in fig. 6, not opposite to the eyepiece.

Fig. 1
Scale 1 inch = 3 feet

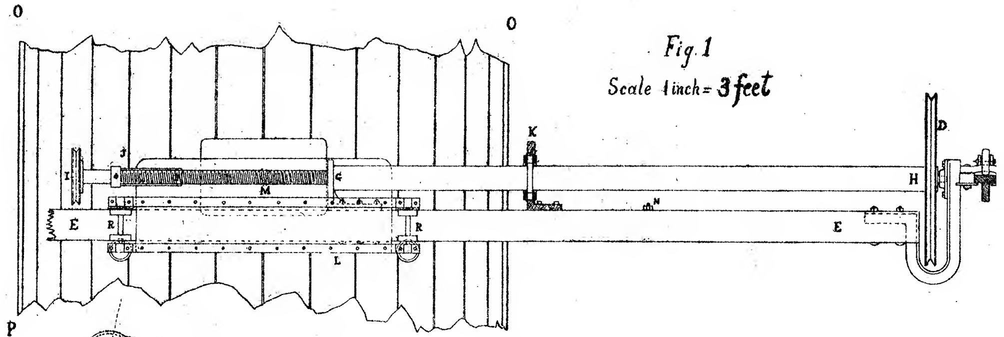


Fig. 3 Scale 1 inch = 9 feet

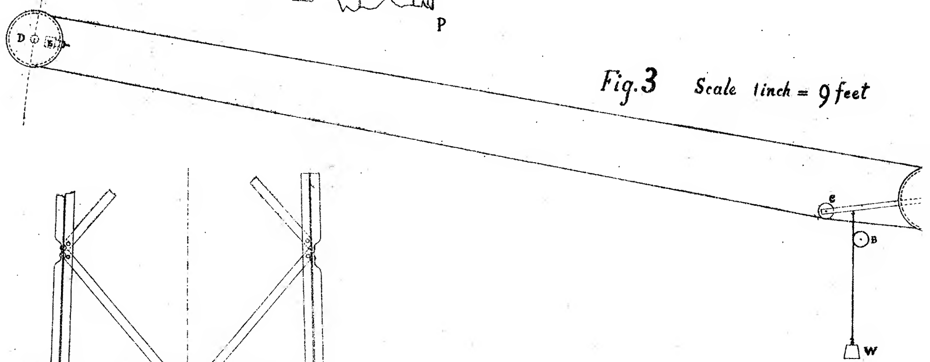
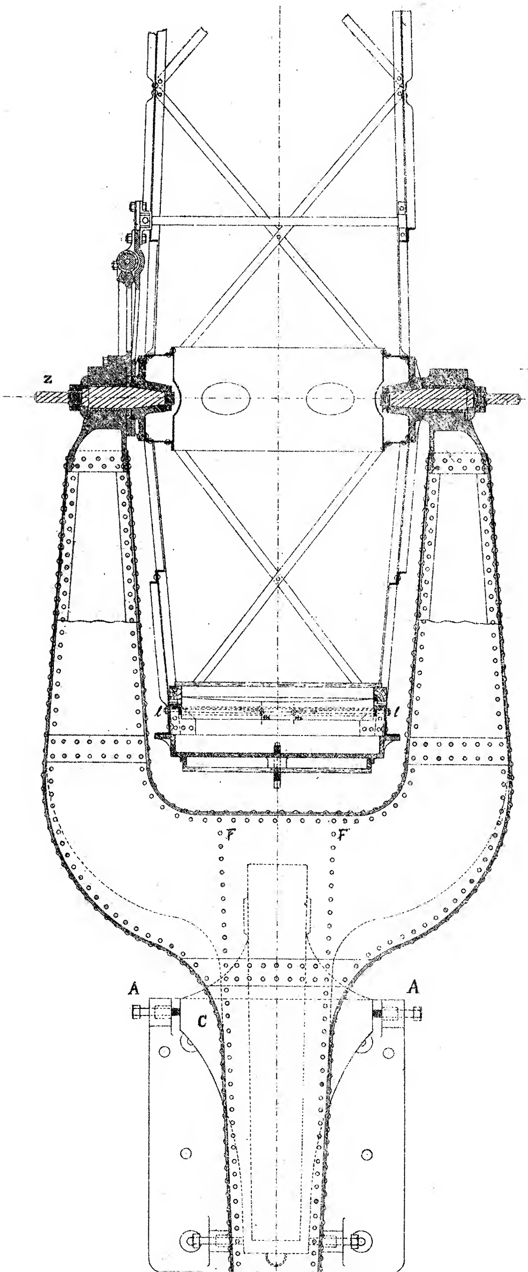
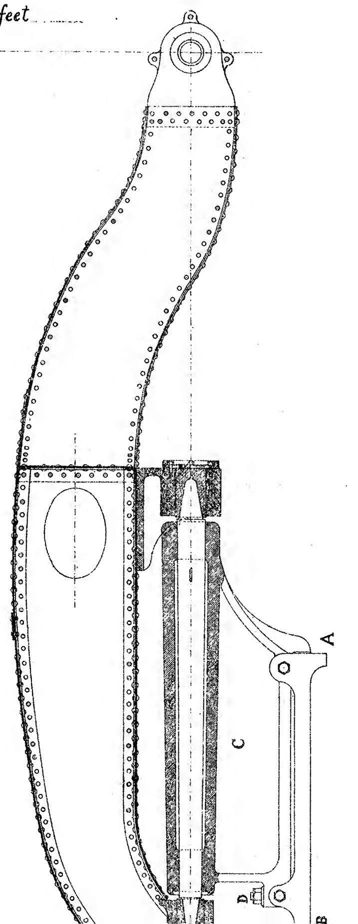


Fig. 4

Scale 1 inch = 3 feet





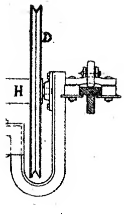
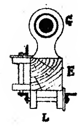


Fig. 2



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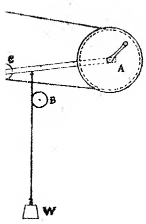

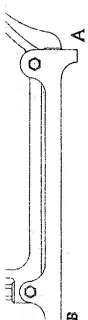

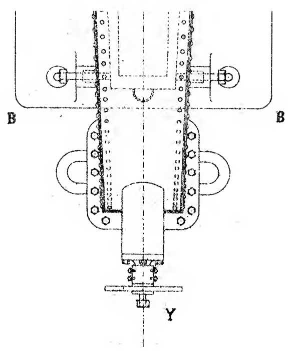
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B
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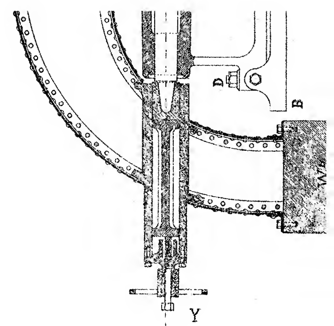
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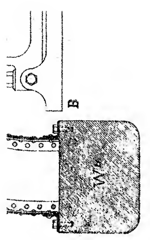
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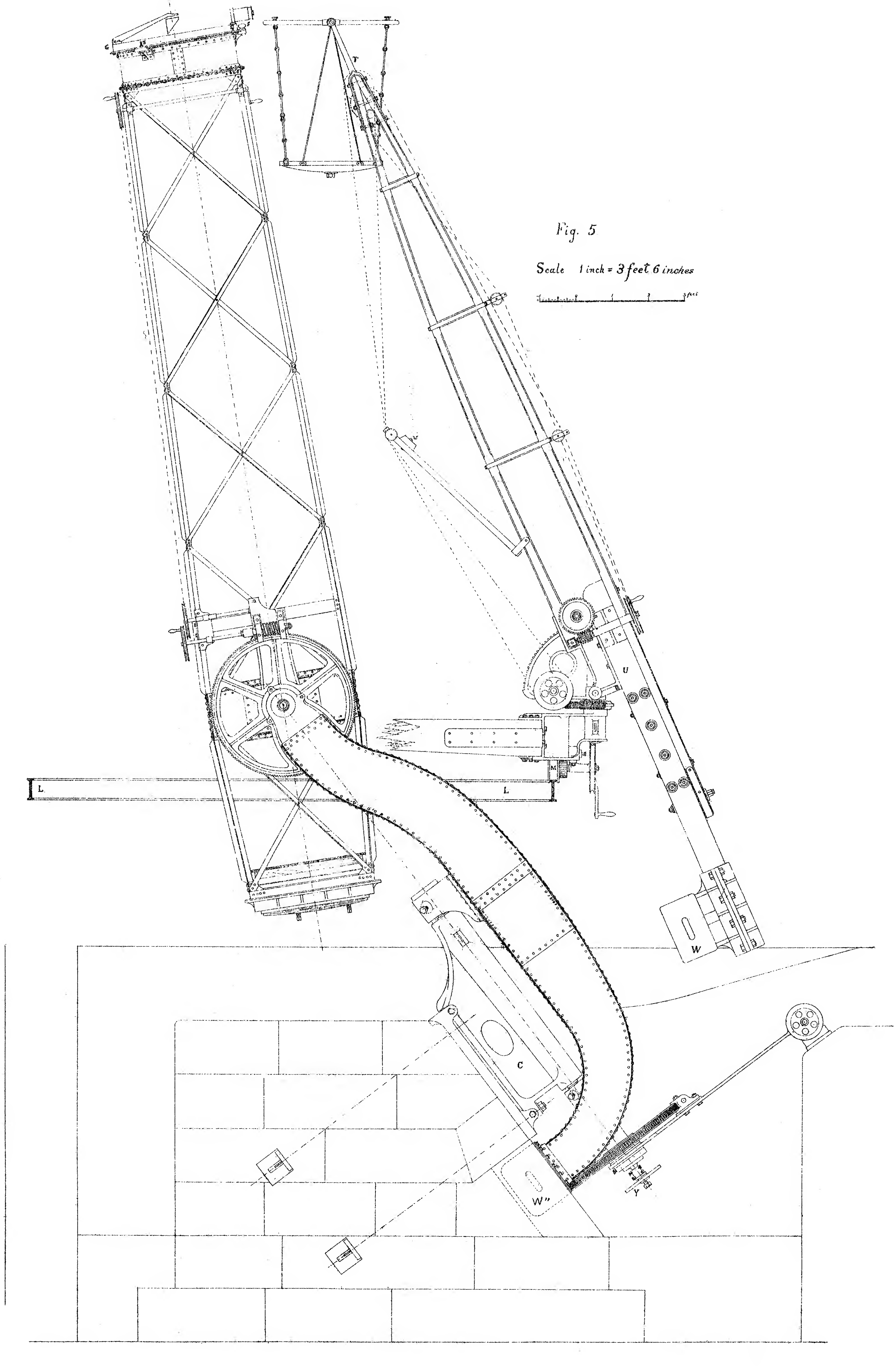
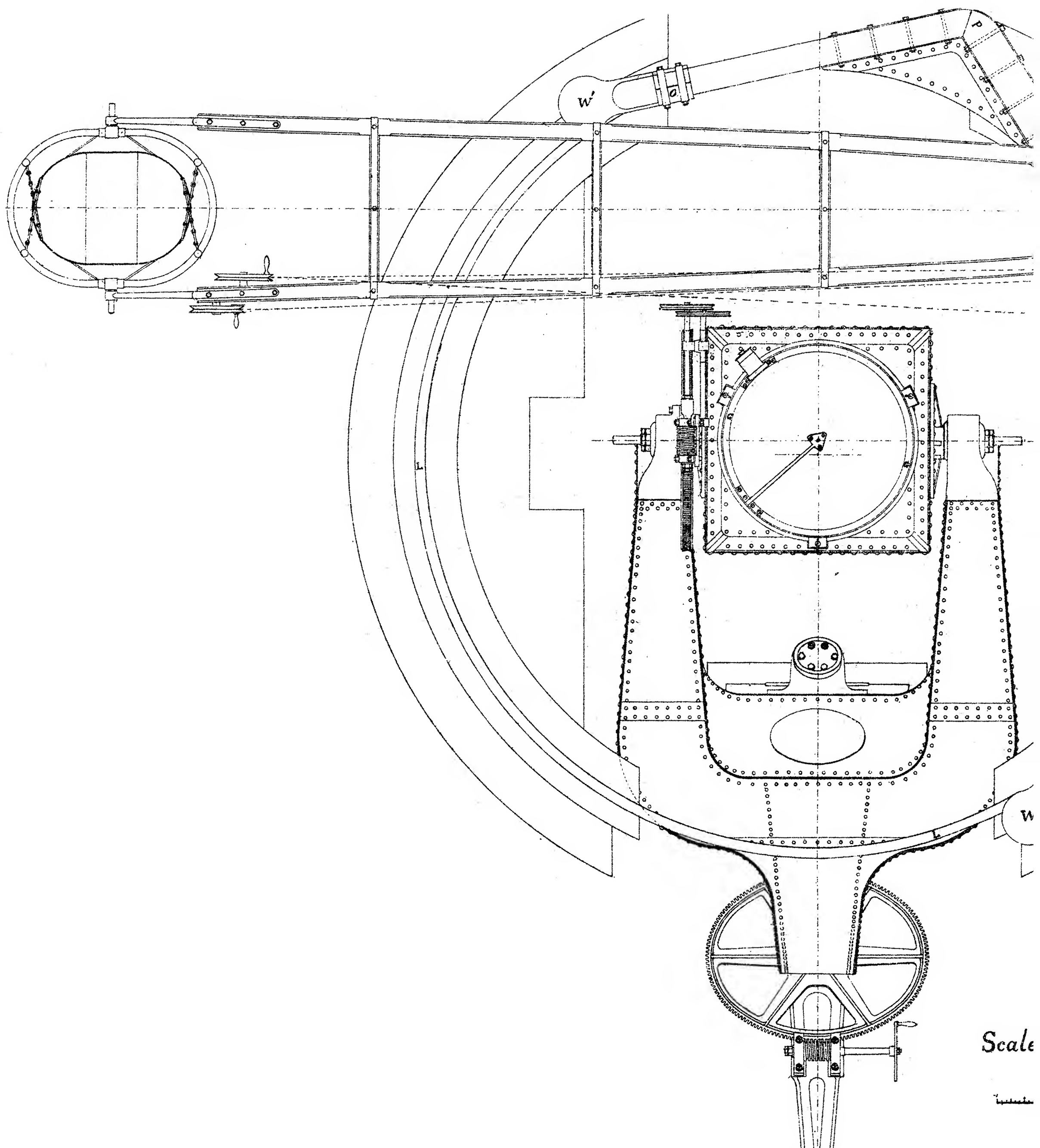


Fig. 5

Scale 1 inch = 3 feet 6 inches

Whiteman & Bass, Photo-Litho, London.



Whiteman & Bass, Photo-Litho, London.

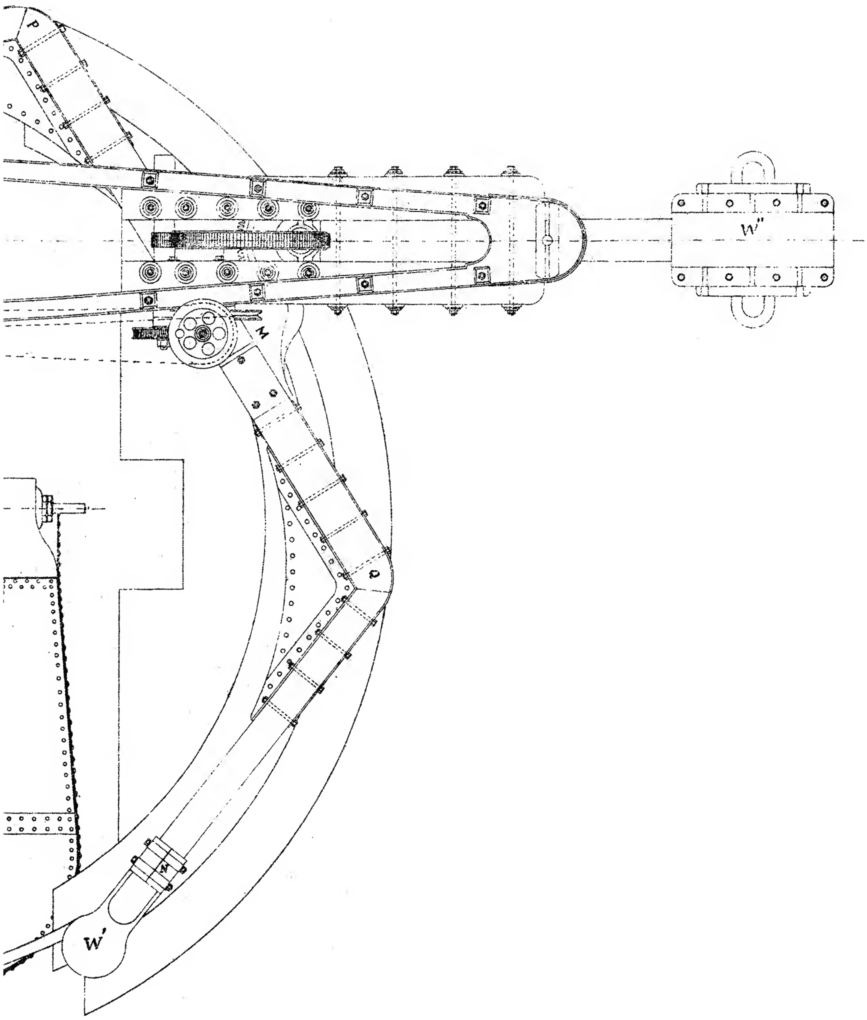
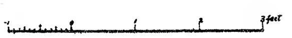


Fig. 6

Scale 1inch=3feet



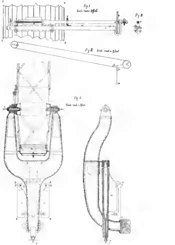


Fig 1
Scale 1inch = 3feet
Fig 2
Fig 3 Scale 1inch = 3 feet
Fig 4
Scale 1inch = 1feet

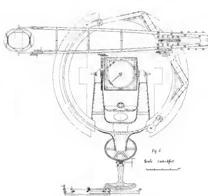


Fig 6

Scale 1 inch = 8 feet

Phil. Trans. 1889 Plate 13